PATENT SPECIFICATION

717,075

Date of Application and filing Complete Specification: June 5, 1952.
No. 14273/52.
Application made in Germany on June 5, 1951.
Application made in Germany on Oct. 13, 1951.
Application made in Germany on March 13, 1952.
Complete Specification Published: Oct. 20, 1954.

Index at acceptance:—**Classes 40(3),** S; **and 40(5),** L26(E3X: FX: G1A).

COMPLETE SPECIFICATION

Improvements in or relating to Multi-Channel Pulse Communication Systems

We, TELEFUNKEN GESELLSCHAFT FUR DRAHTLOSE TELEGRAPHIE M.B.H., a Company recognised under German laws, of 76, Gottinger Chaussee, Hanover, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to multi-channel pulse communication systems of the kind in which intelligence is conveyed by modulated impulses, the impulses appropriate to each intelligence channel being timespaced and occurring in the spaces between those appropriate to the others. In such a system, supposing there are n intelligence channels there is first produced a pulse sequence (the summation sequence) of pulses occurring at a frequency nf (where f is the pulse frequency of each intelligence channel) and, by some suitable method of pulses for the various intelligence channels (pulses No. 1, n+1, 2n+1 . . . and so on for the first channel; pulses No. 2, n+2, 2n+2 . . . and so on for the second channel . . .) separated and passed to n circuits where they are intelligence modulated, demodulated or changed in modulation as may be required. In the case of a transmitter, the pulses, after modulation are all combined in a single impulse channel (a pulse summation channel) and transmitted e.g. on a decimetre carrier wave. The reciprocal process occurs at reception the received impulse summation channel being first split into the component intelligence channels thus to reproduce the original n impulse intelligence channels for demodulation.

There are many known methods for effecting the necessary separation of the intelligence channel pulse sequences from the summation channel sequence at the transmitter or at the receiver. For example motor driven channel distributor switches with rotors driven in synchronism with the impulse sequence frequency have been used to connect the summation impulse circuit sequentially to the intelligence channel circuits at the proper times. Mechanical switches are, however, not suitable for speech or indeed for other than more or less simple telegraph systems. Accordingly so-called electron beam switches have been proposed for use as distributors but these are complex and costly and difficult to time correctly. Other proposals e.g. the use of so-called ring counters of the valve type, are costly requiring a great many valves.

It has also been proposed to effect separation with the aid of phase-displaced sinusoidal voltages of single (intelligence) channel frequency superposed on the summation channel additively or multiplicatively. This method however is only satisfactory in the case of impulses with relatively low impulse sequence frequency. Higher impulse sequence frequencies, such as are used in connection with multi-signal transmission systems with channels closely spaced in time, require the use of a sinusoidal voltage of too large an amplitude.

The present invention seeks to provide improved means of separation without the defects of the known proposals. In spite of considerably lower cost, the invention gives high stability and reliability as good as and in some circumstances better than those of complex valve circuits. As will be seen it is possible by the invention to effect separation from the impulse summation channel without using any valves at all.

[*Price* 2/8]

The invention consists essentially in superimposing, either simultaneously or in steps, at least two periodic selection voltages of different frequency on the summation sequence. The wave form and amplitude frequency and relative phases of these periodic selection voltages are so selected that the curve of the resultant wave has a more or less flat top from which a pulse to be separated projects, falling away fairly steeply on both sides of the top where it is of such amplitude as to facilitate separation of the projecting pulse by amplitude selection.

The same selection voltages are suitably phase displaced and used for the selection of a plurality of impulse sequences from the impulse summation channel; this is done by phase shifting the selection oscillations produced for one channel to make them utilisable for the selection of another channel or group of channels. For this purpose any known phase shifter arrangements can be used. The simultaneous or successive combination of periodic selection frequencies and summation channel pulses can be done by a multiplicative method, for example with the aid of valves, or by an additive method.

It is very advantageous to use sinusoidal oscillations as the periodic selection voltages. Preferably the lowest frequency oscillation is a sinusoidal oscillation of frequency equal to the impulse sequence frequency of an intelligence channel (or a group of channels) and higher frequency selection oscillations are made integral multiples of said impulse frequency of one channel. The higher frequency oscillations can also be sinusoidal oscillations, but other wave forms can be used.

The resulting combined voltage wave has a more or less steep sided wave form depending on the number of harmonics used and this much increases the facility of amplitude selection of the pulses and therefore enables higher impulse sequence frequencies to be handled. Even when using only two sinusoidal voltages the result is much improved as compared to the use of only one selection frequency of equal amplitude. For the same reason the combined voltage wave amplitude can be made low with consequent reduced liability to disturbance by unavoidable voltage fluctuations.

It is often better to effect the selection of individual intelligence impulse channels from the impulse sequence of the summation channel in successive steps instead of in one step. Especially is this so when, for practical reasons, a separation of groups of intelligence channels into a channel group of small summation impulse frequency is advisable, the modulation or demodulation of the individual intelligence channels being carried out by separation of the said individual channels from a group. In such cases the impulse sequence of the summation channel, for example when using only two selection voltages, is superposed first only with a mean selection frequency lying between the summation channel frequency and an individual intelligence channel frequency and the group summation channel resulting therefrom (of mean impulse sequence frequency) is then superposed in a further step with a selection oscillation corresponding to one individual intelligence channel frequency. This will be more fully explained later.

The invention is illustrated in and further explained in connection with the accompanying drawings.

The method employed by the invention will first be described in rather more detail for the simple case where only two sinusoidal voltages of different frequency are used. Referring to figure 1 the second and third lines represent two sinusoidal selection oscillations *b* and *c* shown in conventional manner with voltage against time. The top line is a regular sequence of time spaced impulses *a* for eight channels numbered 1 to 8. The fourth line represents the summation *d* of the curves *a*, *b* and *c* and it will be seen that curve *d* rises above a threshold value *e* at regular intervals—as drawn when the impulses proper to channel 3 occur. Accordingly an impulse sequence of impulses g3 can be separated and subjected to suitable modulation for intelligence purposes. Thus, for example in a multiplex eight channel system 64,000 impulses per second might be produced at the transmitter and, by the foregoing method, eight impulse sequences for the eight signal channels are isolated, separately modulated, time-stepped and transmitted. In reciprocate fashion the eight impulse sequences can be again separated from the received impulse sequence at the receiver and the individual signals re-obtained. A comparison of the curve *d* with a corresponding individual selection oscillation *b*, indicated in broken lines on the right hand side of the fourth line in figure 1 makes evident the considerable advantage of the use of two selection oscillations in steepening the slope of the curve. This advantage is still more marked in a transmission system with a still higher number of channels, for as the number of channels increases the impulses come closer together and are therefore more difficult to separate. For example, if there were 24 channels each with an impulse fre-

quency of 8,000 pulses per second the impulse frequency of the summation channel would be 192000 pulses per second and therefore the distance between two adjacent pulses would be only 1/192000ths of a second i.e. in terms of the selection oscillation of 8 Kc/s, a phase angle of only 15°. In this time an 8 Kc/s sinusoidal voltage amplitude falls from its maximum by only 3.4% and separation therefore requires a very highly constant threshold voltage and even so only very small amplitude impulses can be used. If however, two selection oscillations of 8 Kc/s and 48 Kc/s are used with the voltage proportion selected at about 0.68/0.32, the combined or summation amplitude will drop (at the same point of time considered) by 32% so that the tops of the appropriate pulses will be similarly separated in amplitude. Therefore the summation voltage of the selection oscillations can be much lower (for example about 1/10th of the case where only one frequency is used) or correspondingly larger amplitude pulses can be used. The invention is easily applicable to still higher numbers of channels, for example 96 and more. The attainable accuracy of selection rapidly increases (owing to increasing steepness of the curve of the composite selection wave) with increase in the number of different selection oscillations simultaneously used to produce that wave—assuming, of course, skilful selection of the individual frequencies and amplitudes.

In figure 2 is a highly simplified diagram of an arrangement operating as described and using only two selection frequencies. The selection oscillations b and c and the impulse sequence a are fed through transformers T_a, T_b, T_c with their secondaries in series with one another and with a rectifier Ge to which threshold voltage bias $+e$ is applied at the terminal so marked. Only those impulses which exceed the bias $+e$ are passed by the rectifier Ge and these form the impulse sequence g which alone passes to the transformer Tg. The pulses of this sequence are signal modulated by modulating voltage m supplied through transformer T_m whose secondary is in series with a voltage biassed rectifier G_m. The resultant amplitude modulated pulses as represented at g^1 are taken off from across resistance R. A similar arrangement is provided for taking off each channel sequence of pulses (from the original total pulse sequence) and modulating the pulses of that channel. The output resistance R may be common to all the channels from which will therefore be derived a modulated summation channel consisting of a number of separately modulated pulse channels.

Similarly, at a co-operating receiver the impulse sequences of the individual channels are separated from the impulse sequence of the incoming summation channel.

Additive or multiplicative summation of the various voltage components can be attained by non-linear devices other than as so far described, e.g. electron valves (such as diodes, triodes, and multigrid valves). The addition of the individual voltages as in figure 2 by means of transformers is only one example.

Transformers and coupling elements used in arrangements in accordance with this invention may be common to several channels or may be omitted (depending on design) if undesired inter-channel reaction is prevented or not present—e.g. where electron valves or capacitive bridged transformers of negligibly small inter-channel reaction are used. On account of the relatively small amplitudes of the selection oscillations and the fact that relatively large parallel capacitances may be used on the secondary sides of the transformers, the liability to cross talk can be made very small and such elements may be common to several channels. Thus, by proper design, it is possible in a system comprising 24 channels each of 8 Kc/s to use only two transformers for a selection oscillation frequency of 48 Kc/s (a good practical figure to choose) with a phase displacement of 90° to each other and each of which has two phase opposed secondary windings. In this way four 48 Kc/s selection oscillations each displaced by 90° are made available, to which twenty four 8 Kc/s oscillations, each displaced by 15° and correspondingly fed through 12 transformers, are added. Accordingly a total of only two valve generators and 16 transformers is necessary as against the minimum of 24 valves which would be required were a ring counter used. The increased reliability due to so greatly reduced a number of valves (as well as the increased stability) is evident.

The method of the invention is applicable in much the same way to the transmitter side as well as to the receiver side of a system and the impulse modulation may take different forms as desired e.g. amplitude, width or phase modulation may be used. The invention lends itself especially to the provision of systems in which valve arrangements used for example for impulse generation, amplification or alteration of the kind of modulation, are common to all channels or at least large numbers of channels.

In carrying out the invention fre-

quency multipliers (with their high stability) may with advantage be used for the generation of the selection oscillations instead of using the less stable frequency dividers. The selection oscillations can also be generated in automatic oscillators, which are phase-stabilised by the impulses. Frequency multiplication affords considerable advantages as against frequency division when used in conjunction with the selection method illustrated.

The superposition of the different selection voltages with the impulse sequence of the summation channel carried out in successive steps is graphically illustrated in figure 3, again for the case where only two sinusoidal voltages of different frequency are used. The impulse sequence *a* for channels 1 to 8 are first superposed on the sinusoidal voltage *b* of higher frequency resulting in the summation voltage *c*. As will be seen this periodically exceeds a suitably selected voltage threshhold e_1 at times such that the impulse sequence $g_{3,7}$ (consisting of the sequences appropriate to two channels namely channel 3 and channel 7) is separated from the summation channel *a*. The same method is then used for the separation of the individual channel sequences for channels 3 and 7 from this impulse sequence. The impulse sequence $g_{3,7}$ is superimposed on a sinusoidal voltage *d* corresponding to one of the individual channel frequencies (that of channel 3 as illustrated) to give the voltage wave *f*, from which the impulse sequence g_3 (channel 3) is separated by the aid of a second threshold voltage e_2 for application to a modulator, demodulator or modulation converter depending on the subsequent use and whether the case is one of transmission or reception.

The selection oscillations *b* and *d* must of course always be so chosen that their frequencies correspond to the appropriate individual channel frequency or an integral multiple thereof and should be such that their curves rise steeply so that at the amplitude limitation of the summation voltage, interference impulses are not likely to exceed the threshold voltage used for selection. By choice of sufficiently high frequencies and careful maintenance of correct phasing excellent results are attainable. There is indeed some advantage in the method of figure 3 as compared with the simultaneous superposition of the component voltages (figure 1) since the separate adjustment and control of the correct phase position for the various sinusoidal oscillations can be effected with less expenditure and trouble than is necessary for phase displacement and adjustment of an often very complex composite voltage wave consisting of several component oscillations (*d* in figure 1).

A further advantage of the method of figure 3 can be seen by a comparison of figures 1 and 2. Whereas in figure 1 the threshold voltage *e* must be at least equal in amplitude to the main maximum of the composite voltage resulting from the superposition of the two sinusoidal voltages *b* and *c*, in figure 3 the threshold voltage need only be equal to the amplitude of the sinusoidal voltage superposed at the time with the impulse sequence and this is considerably lower (in the present example, about half). The voltage limitation is carried out, it is true, in several steps (in the present example in two steps) but the voltage load on the rectifier effecting separation is dropped to a corresponding fraction (in the present example about half).

Figure 4 shows, in simplified manner, a circuit for carrying out the method of figure 3. The impulse sequence *a* and the selection oscillation *b* are fed through transformers Ta and Tb to a circuit containing a voltage biased rectifier Ge_1. Only the impulses of the sequence $g_{3,7}$ in the summation voltage *c* which exceed the threshold $+e_1$ determined by the voltage bias on this rectifier pass the rectifier Ge_1 and are therefore transmitted by means of the transformer T_{g1} to a circuit containing the rectifier Ge_2. The second selection oscillation *d* is fed in to this circuit through the transformer Tc and further amplitude limitation of the summation voltage *f* is effected by a rectifier Ge_2 which is voltage biassed by voltage $+e_2$. Thus only the impulse sequence g_3 containing the channel 3 impulses is transmitted to the modulation circuit by means of the separation transformer T_{g2} and is amplitude modulated by the modulation rectifier Gm to which the modulation voltage *m* is supplied through the transformer Tm.

A similar arrangement is necessary in a multiplex system for each impulse channel to be selected. As in the case of figure 2, however, the output resistance R can be common to all the channels and here also several transformers or coupling elements can be common to different channels or be omitted altogether if interchannel reaction is otherwise prevented.

What we claim is:—

1. A multi-channel modulated impulse signal communication apparatus wherein each intelligence channel utilises a sequence of impulses and the impulses are all combined in an impulse summation channel from which the pulses of the separate intelligence channels must be separated for modulation, demodulation or other use characterized in that for the

separation of each intelligence channel the impulse sequence of the summation channel is combined with at least two periodic selection voltages of different frequencies either simultaneously of in steps first with one of said voltage and then of the resultant with another to produce a composite wave with relatively flat tops from which the appropriate intelligence channel impulses project and which recur periodically at the impulse frequency of and substantially in phase with the impulses of the intelligence channel to be separated, the same periodic voltages, suitably phase displaced, being used for the separation of a plurality of intelligence channels the wave form being of relatively steep curvature on both sides of said relatively flat tops, so that the projecting intelligence channel impulses can be separated by amplitude selection.

2. Apparatus as claimed in claim 1 wherein the combination is effected additively.

3. Apparatus as claimed in claim 1, wherein the combination is effected multiplicatively.

4. Apparatus as claimed in any of the preceding claims, wherein the periodic selection voltages are sinusoidal oscillations.

5. Apparatus as claimed in any of the preceding claims, wherein the frequency of one of the periodic selection voltages is chosen equal to the impulse frequency of an intelligence channel (or of a group thereof), and the others are chosen as integral multiples thereof.

6. Apparatus as claimed in any of the preceding claims, wherein periodic selection frequencies are obtained by frequency multiplication or division from the impulse frequency of an intelligence channel (or of a group of channels) or are synchronised by said impulse frequency.

7. Apparatus as claimed in claim 1, wherein amplitude selection is effected by transforming or coupling elements in association with biassed rectifiers.

8. Apparatus as claimed in claim 8, wherein transforming or coupling elements common to several channels are provided.

9. Apparatus as claimed in claim 1 wherein the combination is effected simultaneously and the periodic selection voltages and the impulse sequence of the summation channel are fed in through transformers having their secondaries in series with one another, with a unilaterally conductive device, with an output device and with a source of threshold voltage.

10. Apparatus as claimed in claim 1 wherein the combination is effected in steps and each step of combination is effected by a circuit into which the waves to be combined are fed through transformers and which includes, in series, the trnsformer secondaries, an unilaterally conductive device, an output device and a source of threshold voltage.

11. Apparatus as claimed in any one of claims 1 to 3, wherein each tap of a time delay circuit feeds into a mixer-selector whose second input consists of the pulses of the summation channel, the outputs from the mixer-selectors being subjected to amplitude selection.

12. Apparatus substantially as herein described with reference to the accompanying drawings.

HASELTINE, LAKE & CO.,
Agents for Applicants,
28, Southampton Buildings,
Chancery Lane, London, W.C.2.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1954. Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

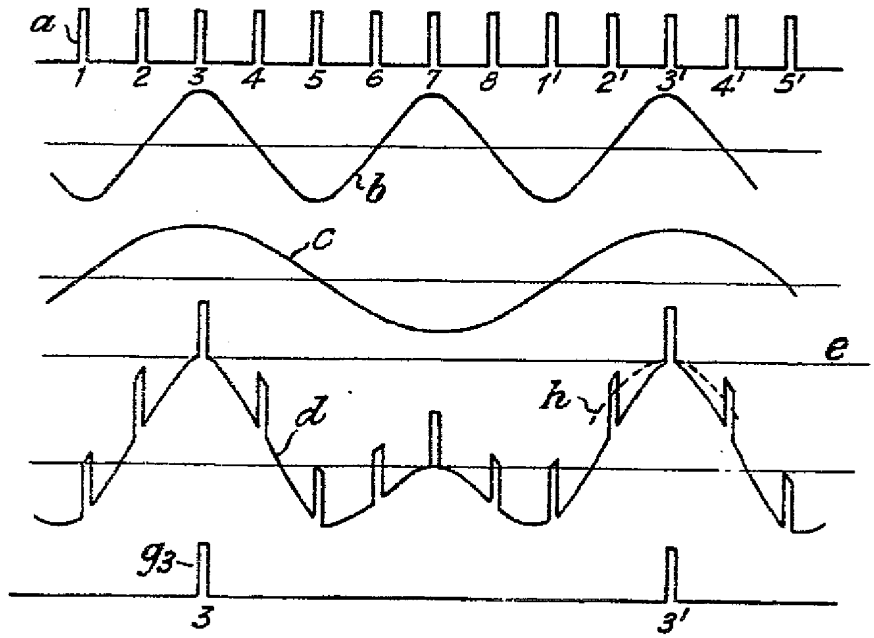

Fig. 1.

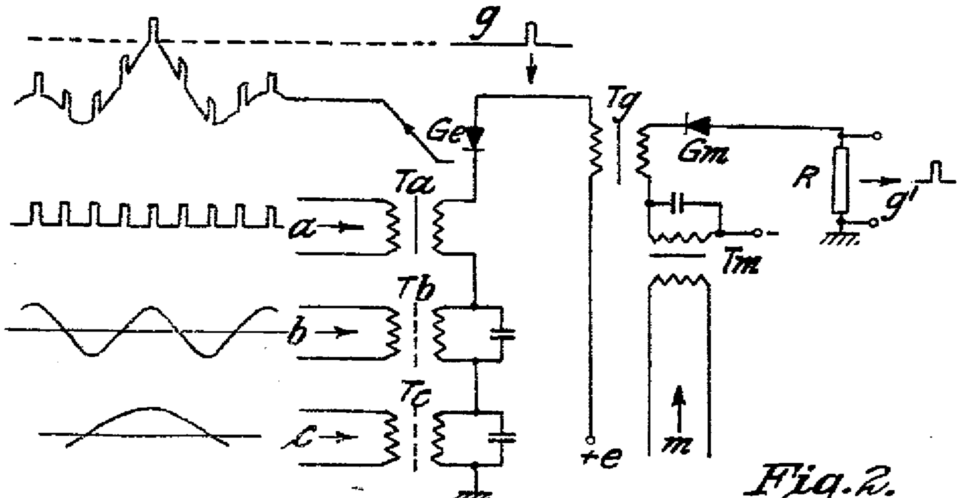

Fig. 2.

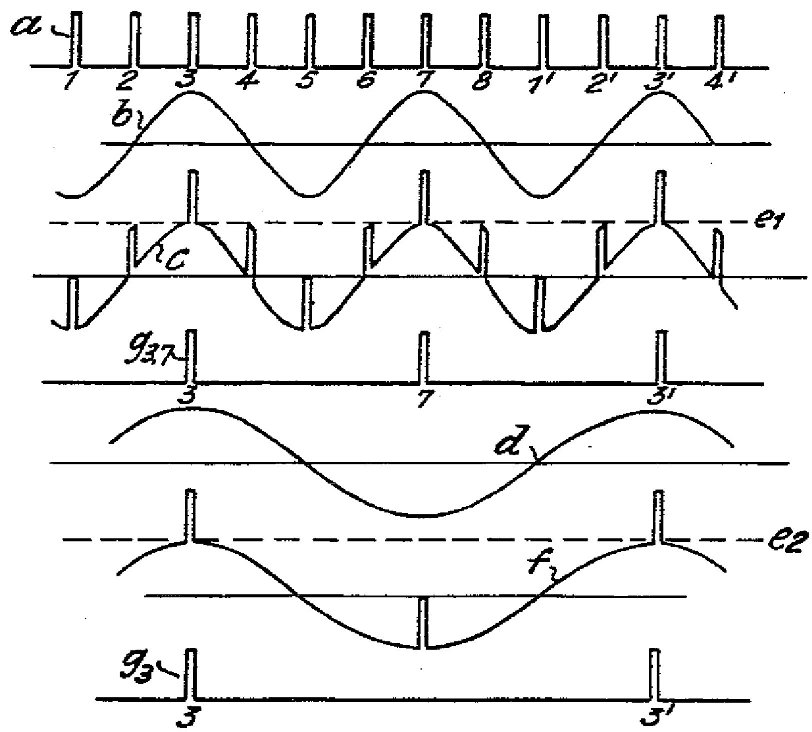
a
1
2
3
4
5
6
7
8
1'
2'
3'
4'
b
e1
c
g3,7
3
7
3'
d
e2
f
g3
3
3'

Fig.3.

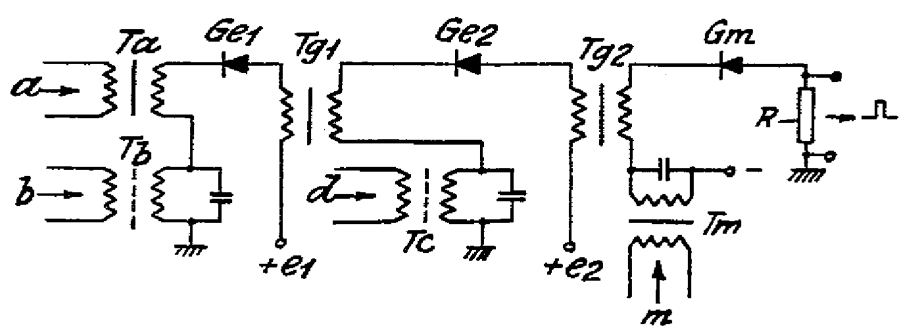
Ta
Ge1
Tg1
Ge2
Tg2
Gm
a
R
Tb
b
d
Tc
+e1
+e2
Tm
m

Fig.4.

717,075 COMPLETE SPECIFICATION
2 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

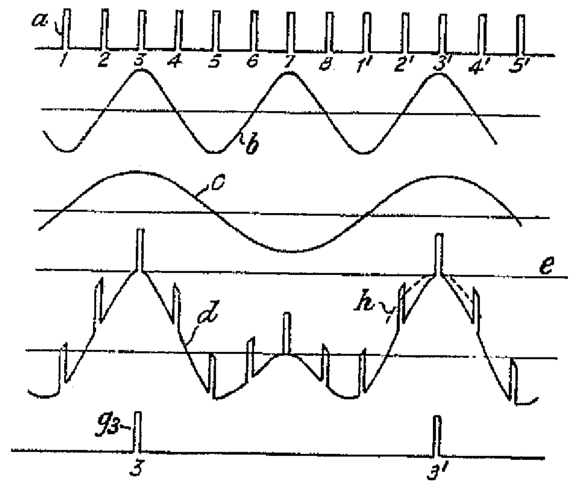

Fig. 1.

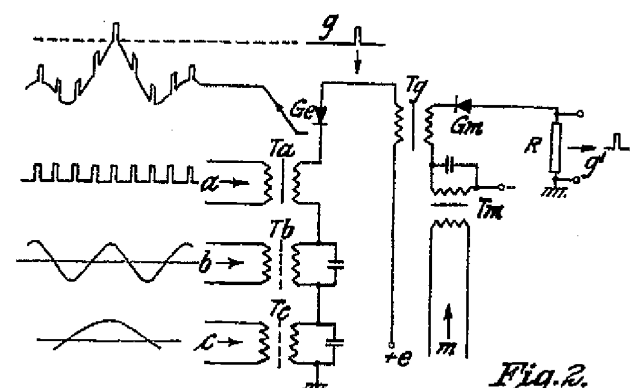

Fig. 2.

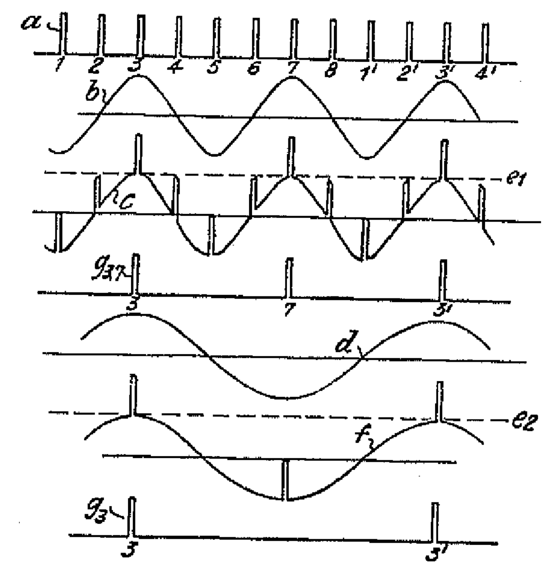

Fig. 3.

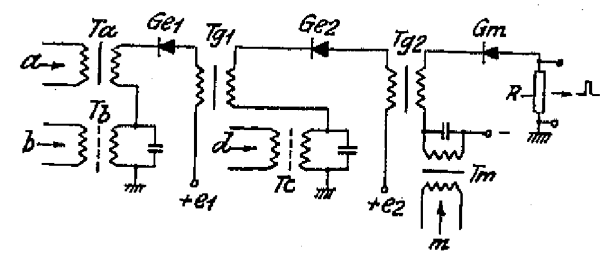

Fig. 4.